

Designing a regeneration zone for the Cuyahoga River Valley: Ecological restoration

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Summary

The potential for ecological restoration of the lower Cuyahoga River is presented as part of a planning for a Regenerative Development Zone (RDZ) in industrial/commercial land near downtown Cleveland. First, hydrology, water quality, and fish and invertebrate data and composite biological indicators are presented for this lower reach of the Cuyahoga River. While there are some signs of recent improvement in river fish richness, the biological indicators generally still indicate poor aquatic habitat. Channel dredging, large ship use, and rigid shoreline pilings limit the diversity of habitat and ensure continual resuspension of chemically contaminated river sediments. We present three general alternatives for restoration of the riverine system. One is the creation of 70 acres of oxbow wetlands on the floodplain terrace with seasonal hydrologic connections to the river but otherwise with connections to upland urban runoff. A second alternative is for the restoration of a 0.5-mile reach of a tributary stream, Kingsbury Run, to the Cuyahoga River, thus avoiding some of the problems associated with restoration of the Cuyahoga River itself while providing a significant habitat connected to the river. A third alternative considered is 5.6 miles of “pocket wetlands” along the Cuyahoga River riparian edge itself. Costs and ecological benefits of each of these options are provided. Cessation of river channel dredging and improvement in water quality in the upstream river are vital to any effective restoration techniques in the lower Cuyahoga River. Data on costs of a detailed study of the lower Cuyahoga River and of demonstration projects that would be needed as the next step are also provided.

Introduction and objectives

This study is part of a larger scale project being undertaken by the Rocky Mountain Institute (RMI) on designing an “urban restoration,” referred to here as a regenerative development, for a 1.75-mile reach of the Cuyahoga River valley in urban Cleveland, Ohio (Figure 1). Planning a Regenerative Development Zone (RDZ) around the river is the beginning of a long process for improving the integrity of a river and revitalizing the local economy. The environmental quality of the RDZ considered here has been degraded for the last two centuries. The RDZ under investigation is located in the heart of industrial Cleveland and includes a stretch of the Cuyahoga River estimated to

be from river mile 3.26 to 5.0.

Our study, as part of the larger effort by RMI, will attempt to do the following:

1. Determine the extent of the ecological problem in the regeneration development zone described above in the Cuyahoga River Valley.
2. Identify alternative levels of ecological restoration that are possible.
3. Define alternative biological-restoration solutions to achieve these levels of restoration as developed by Cuyahoga River Remedial Action Plan, including Kingsbury Run restoration, pocket parks, and other creative solutions.
4. Identify environmental-quality indicators appropriate to monitor biological restoration over time.
5. Provide a restoration report including renderings of the restoration solutions.

State of the Lower Cuyahoga River

Land use changes (1779 – 2003)

Changes in land use for the Cuyahoga River Valley during 1779 - 2003 were investigated by using historic records, maps, and aerial photos. In 1796, the first settlers set up residence in the Cuyahoga area. The population grew slowly, until 1810 when the number of individuals increased nearly ten-fold. Records indicate that Cuyahoga County experienced a steady population increase between the years 1810 and 1866, and within sixty years from establishment, over 60,000 individuals resided in the county (reference). The population in Cuyahoga County peaked in 1990 at 1,412,140, and has been slowly decreasing since then (1,393,978 in 2000 and 1,363,888 in 2003).

Increased population and urbanization led to conversion of the natural habitats in the lower Cuyahoga River (e.g. forest, prairie, wetland) to urban areas and agriculture. In the late 1700s, when there were few people residing in the Cuyahoga Valley, the undulating landscape surrounding the meandering Cuyahoga River was terraced floodplain. This Lake Plain delta near Lake Erie supported lush grasslands, wetlands, and meandering streams (Figure 2). Two maps in 1796 illustrated the beginning of Cleveland, with extensive development along the Cuyahoga River and Lake Erie in the vicinity of the RDZ (Figures 3 and 4). This strictly urban area extended all the way to the banks of the Cuyahoga River and Lake Erie, leaving little area for floodplain, wetlands, and other natural features.

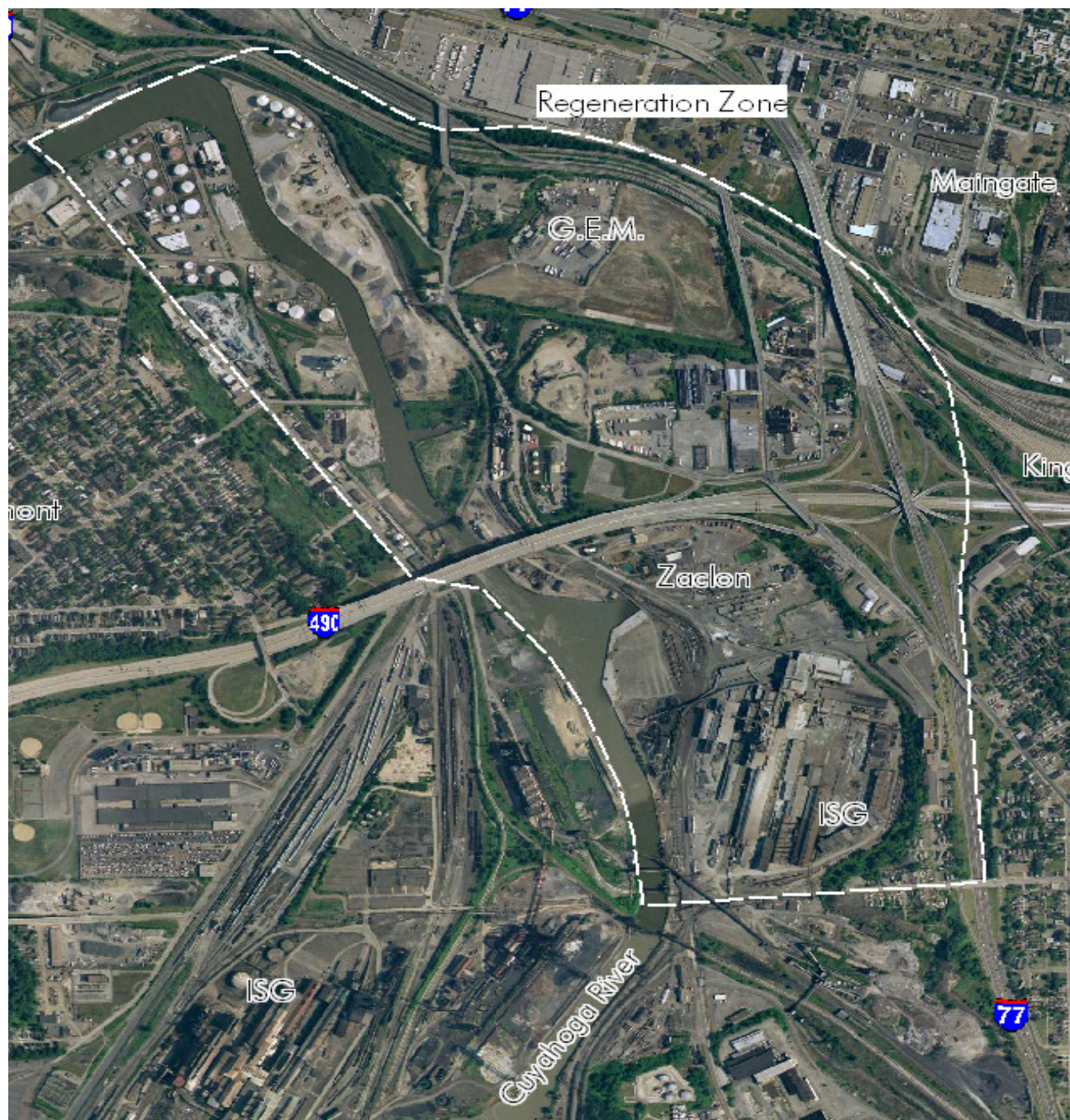
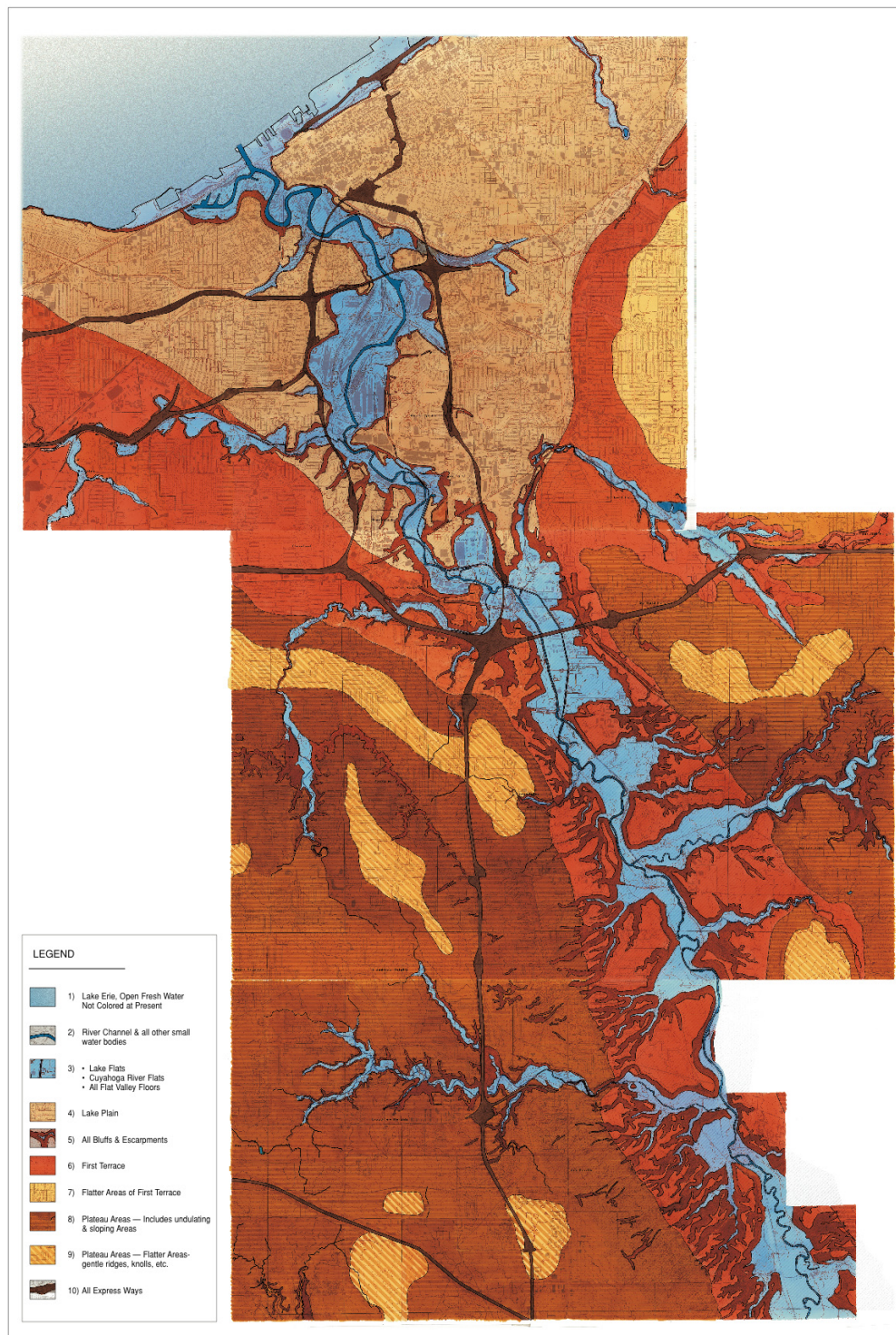


Figure 1. Aerial photograph of Cleveland in 2003. The regeneration zone is outlined by the dashed white line.

By 1835, over 5,000 individuals resided in Cleveland, and the city was expanding rapidly. A map of Cleveland during this time shows the extent of the city development since the plans in the late 1700s (Figure 5). With a population increasing in exponential numbers from 1835 to the middle twentieth century, the city would grow even more. For much of the 20th century, development within this zone was dominated by industry including steel production, petroleum processing and river transportation.

Hydrology

There are no United States Geological Survey (USGS) gage stations in the area, so we selected two USGS gage stations, 0420800 at Independence and 042084504 near Newburg Heights, to assess streamflow and flooding events. Both stations are in Cuyahoga County and collect data upstream from the RDZ. Station 0420800 at Independence is located at latitude 41°23'43", longitude 81°37'48". The drainage area is 707 square miles, and the datum of the gage is 583.57 feet above sea level. Station 04208504 near



Cuyahoga Valley Initiative

PHYSIOGRAPHY

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Figure 2. The physiography of the area surrounding the Cuyahoga River.

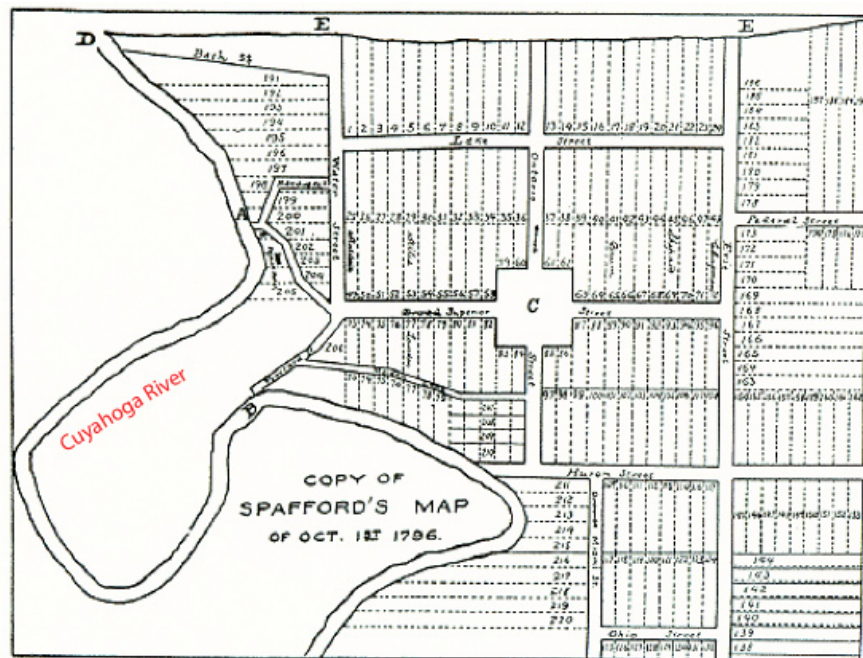


Figure 3 Cleveland with urban development, 1796. 'A' marks the lower landing of the river; 'B', the upper landing; 'C', the public square; 'D', the mouth of the river; and 'E', Lake Erie (made by Seth Pease, from Whittlesey, 1867).

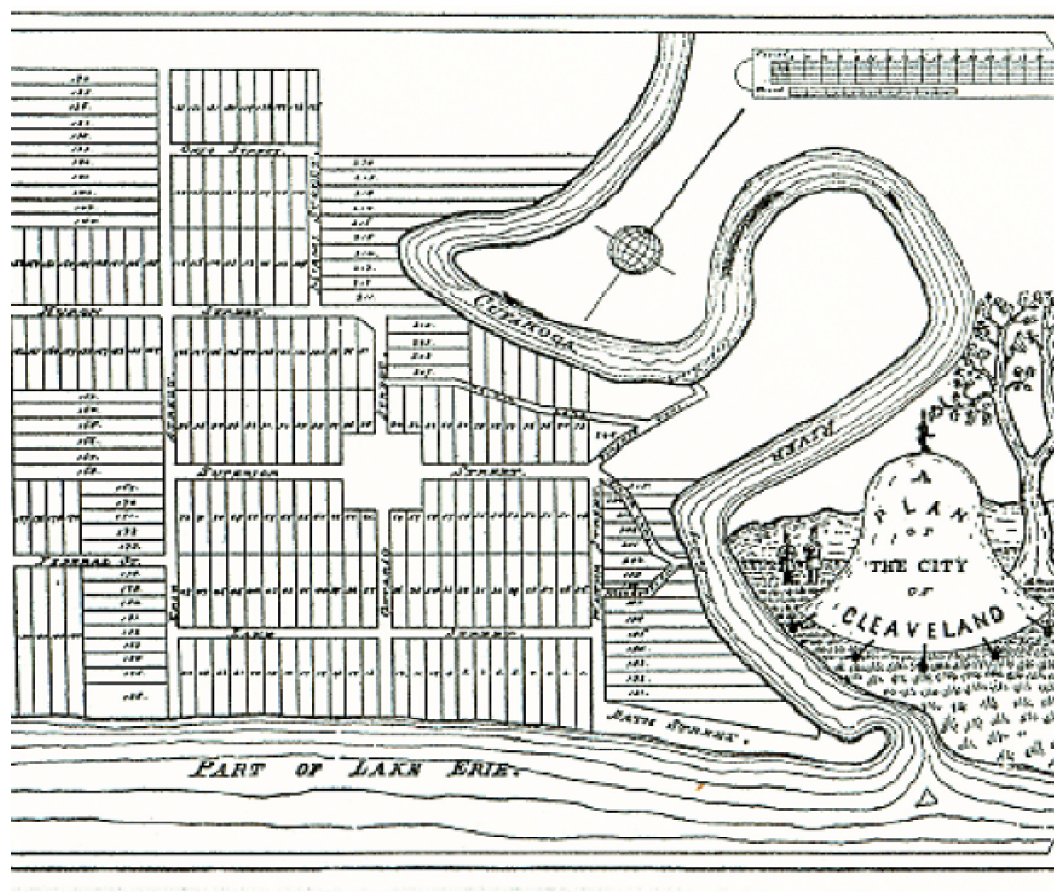


Figure 4 Cleveland with urban development, 1796 (made by Seth Pease, from Whittlesey, 1867).

Newbury Heights is located at latitude $41^{\circ}27'45''$, longitude $81^{\circ}40'52''$. The drainage area is 788 square miles.

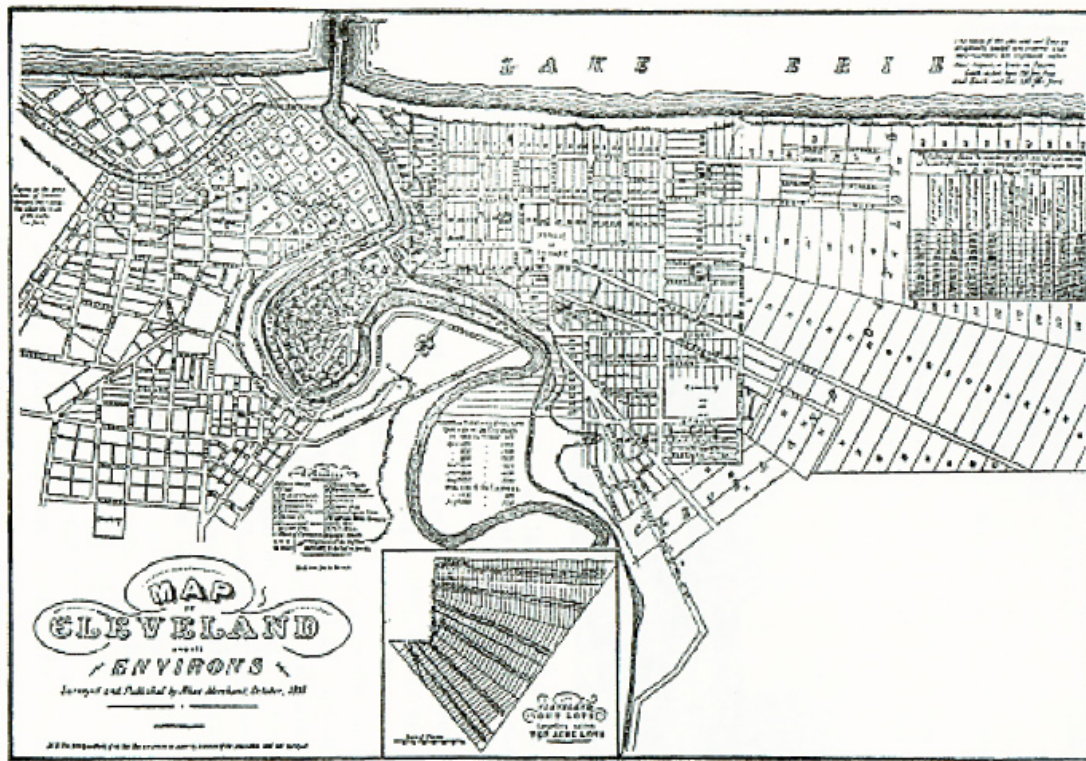
We examined monthly streamflow for station 04208504 near Newbury Heights, which is closest to the RDZ, from a 13-year record (water years 1991–2003). The hydrologic pattern for mean monthly streamflow for these years is similar to other rivers in the Midwest. Winter and spring months (December, January, February, March and April) are characterized by higher discharges as a result of higher precipitation and more surface runoff. The relatively dry summer and fall months (July, August, September and October) have lowest mean discharges.

Daily streamflow for station 04208000 at Independence was obtained for a much longer period of record—81 years from 1921 through 2003—and used to construct a hydrograph. The daily stream pattern has changed significantly since 1921. From 1921 to 1923, there were no flood events (above bankfull) and the river discharge was relatively stable. By 1927, the flashiness of the river began to increase and there were two flooding events in 1927 and one in 1929. From 1940 to 2003, the flashiness and occurrences of flooding events dramatically increased. The river has become unstable and there have been over 20 major flood events since 1940.

The changes in hydrology may be due to alterations of the river via dams, loss of natural hydrologic features (i.e., loss of floodplains and wetlands), and increased surface runoff due to impervious surfaces (i.e., urban development).

Water quality

Water quality is an issue of concern for the Cuyahoga River, especially since the notorious Cuyahoga River Fire of 1969, which triggered the national recognition of the nation's water quality problems and eventually resulted in enactment of the Clean Water Act. Water quality concerns within the last ten years in the Cuyahoga River have included high zinc levels, very low dissolved oxygen, levels of fecal coliform that exceed standards, and high concentrations of phosphorus (Army Corps of Engineers, Table 1). Mean concentrations of total phosphorus, nitrate-nitrite, and total zinc for June through September 1996 increase as they approach the confluence with the lake. In 1996, mean coliform bacteria levels in the Cuyahoga River exceeded high stream flow recreational standards, and in some cases maximum standards; however, most of the high bacteria levels were found just upstream of the



Ahaz Merchant's Map of Cleveland, 1835.

Figure 5. Cleveland in 1835 (Whittlesey, 1867)

Table 1. Water quality concerns (by parameter) for the Cuyahoga River.

Location	Study Period	Parameters	Level Recorded
Downstream from Akron	1999	Zinc	slightly higher than 100 ug/l
West Third St (RM 3.26)	1993	DO	above 1.5 mg/l
West Third St (RM 3.26)	1995-1996	DO	sometimes below 1.5 mg/l
Munroe Falls dam pool	Before 1998	DO	below 5 mg/l
Between Akron and Cleveland	1993	Fecal Coliform	exceeding 1000/100 ml criterion
Between Lake Rockwell and Munroe Falls	NA	Phosphorus	median 0.08-0.1 mg/l
Small river reference sites in the Lake Plain	NA	Phosphorus	median 0.06 mg/l

Regenerative Development Zone (Figure 6). Even though metal (zinc), nutrient (nitrate-nitrite and phosphorus), and bacteria (coliform) concentrations increased toward river mile 0 (the mouth), water quality standards were generally met during the 1996 study. Dissolved oxygen, however, has been consistently low, at times reaching 1.5 mg/L, a level that severely affects the viability of fish and macroinvertebrates (Ohio EPA, 2003).

It has been suggested that the degradation of water quality in the downstream run of the Cuyahoga River is due to industry. There are 21 LTV Steel Corporation outfalls (point source discharges) in the Federal Navigation Channel (river miles 0 – 5.6) alone and although the water in the Federal Navigation Channel generally does not exceed water quality standards, loadings of heavy metals, nutrients, and other pollutants by LTV are suspected to be diluted by upstream water (Ohio EPA, 1999). Before the removal of coking ovens in the LTV plants in 1992 and 1993, ammonia concentrations in the river often exceeded chronic toxicity levels in the summer; removal of the ovens are expected to result in gradual improvements in not only ammonia concentrations, but other water quality parameters, such as dissolved oxygen and cyanide concentrations, as well (Ohio EPA, 1999).

Despite water quality that minimally meets standards, studies show that biological integrity and habitat suitability of the Cuyahoga River is very low. The longitudinal trends for the Index of Biological Integrity (IBI) and Qualitative Habitat Evaluation Index (QHEI) scores for the Cuyahoga River decrease dramatically near the mouth of the river (Figure 7). The IBI score for the Regenerative Development Zone is around 10, indicating that the biological integrity is very poor. The QHEI score for this same area is around 70, which is better than average, even though the physical

characteristics have been described as “silt and clay substrates, deep slow-moving water with no riffles, and minimal amounts of woody debris” (U.S. Army Corps of Engineers, 2004). The facts that the IBI score was very low and the QHEI score was average suggest that the Cuyahoga River may have the physical potential to support a diverse community of fauna (i.e. fish and macroinvertebrates), but is presently impacted by humans in the surrounding landscape in such a way that this support is severely restricted.

Heavy metals, including arsenic, cadmium, chromium, copper, iron, lead, mercury, and zinc, have been found in sediments from Kingsbury Run, a tributary of the Cuyahoga River located within the RDZ. Concentrations of cadmium, chromium, copper, iron, lead, and zinc are especially high compared to other similar studies (Table 2). If the sediments are disturbed, these metals could enter the water column where they could have detrimental effects on life within and around the river, including humans.

Annual maintenance of the Federal Navigation Channel of the Cuyahoga River includes dredging the bottom to a depth of twenty-eight feet (U.S. Army Corps of Engineers, 2004). This dredging directly influences the physical characteristics (i.e., channelization), hugely impacts the available habitat for miles (due to silting), and disturbs sediments containing heavy metals. Although the U.S. EPA has tight restrictions on Cuyahoga River sediment disposal due to the classification of these soils as “heavily polluted” by heavy metals (URL: <http://www.epa.gov/glnpo/aoc/cuyahoga.html>), the very practice of dredging allows for the entrance of these metals into the water column and disturbs the stability of any aquatic benthic habitat that might otherwise develop.

Macroinvertebrate and fish communities

Macroinvertebrates are considered ecological indicators;

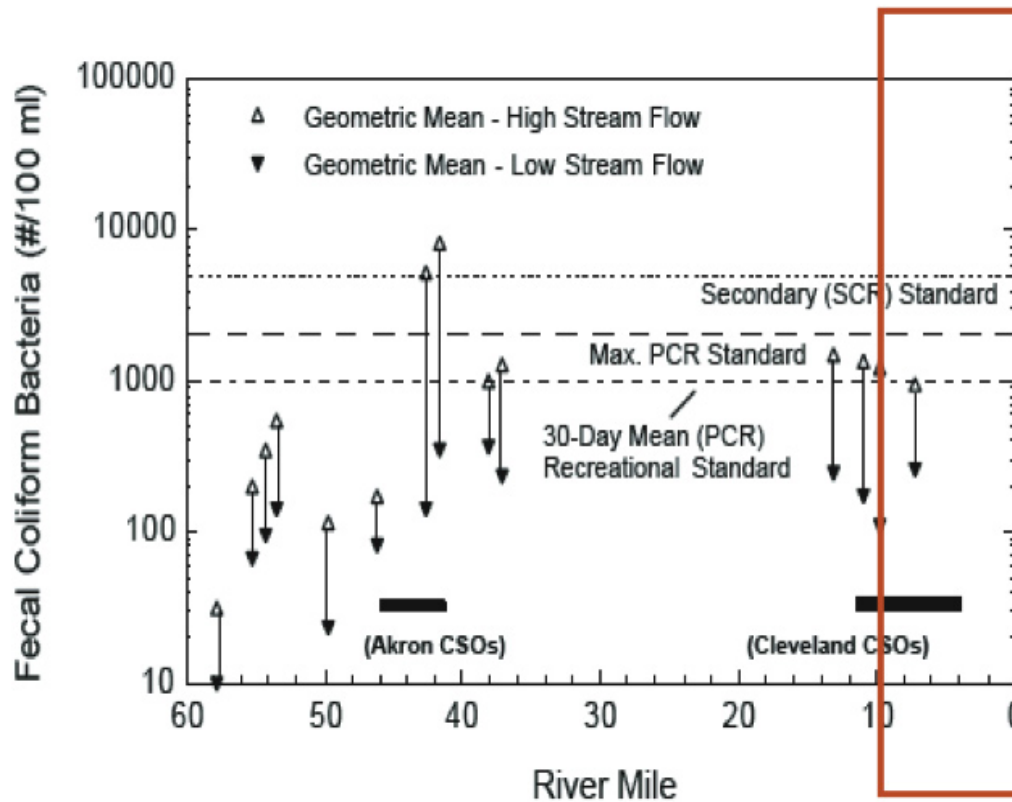


Figure 6. Geometric means of fecal coliform bacteria samples from the Cuyahoga River in the Akron and Cleveland area, 1996. Box approximates the stretch of river within the Regenerative Development Zone.

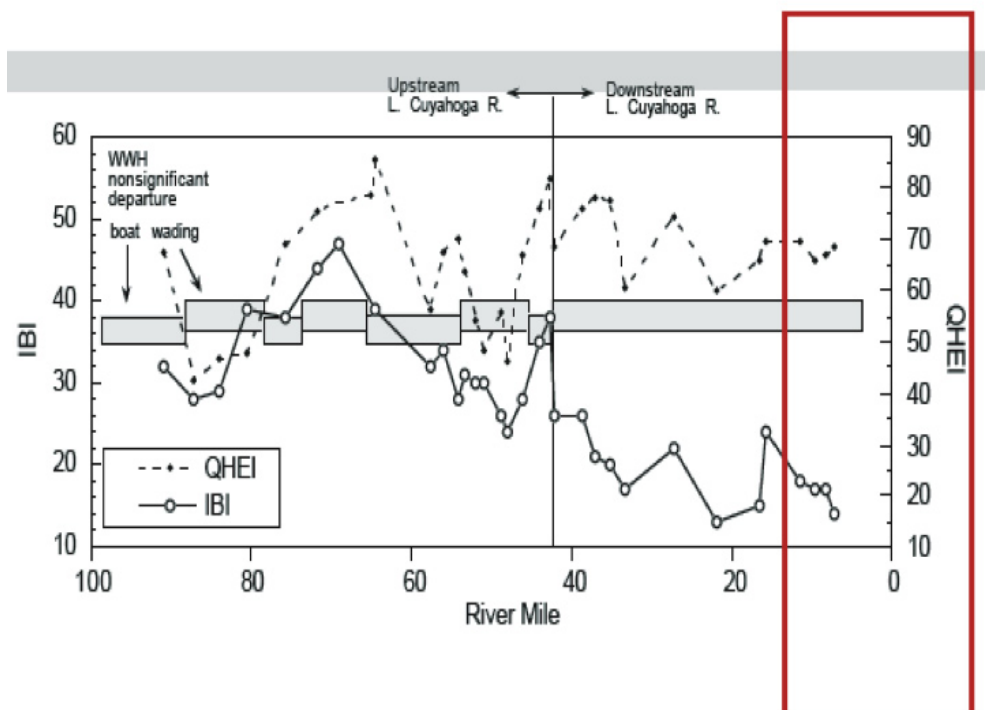


Figure 7. Longitudinal trend of the Index of Biological Integrity (IBI) and Qualitative Habitat Evaluation Index (QHEI) scores at Cuyahoga River sampling sites in 1996. A score of 50 for the IBI and 100 of the QHEI is considered "exceptional". Box approximates the stretch of river within the Regenerative Development Zone.

Table 2. Heavy metal concentrations (mg/kg-dry weight) from sediments collected at Kingsbury Run, located within the Cuyahoga River basin. Percent sands is the percentage (weight to weight) of particles in the sample greater than 60 μ (settling time <0.5 minutes). (From Ohio EPA, 1999)

Sampling Site	River Mile	As	Cd	Cr	Cu	Fe	Pb	Hg	Zn	% Sands
At Mouth	0.1	13.9	2.17	<u>79</u>	91	35,100	107	0.123	<u>435</u>	56
Near Mouth	0.2									
At Mouth	0		1.5	23.4	<u>248.8</u>	<u>127,806</u>	49.4	0.106	<u>1365</u>	56

Values in **bold** - highly elevated concentrations.

Values in **bold** and underlined - extremely elevated concentrations.

Table 3. Biological quality data for river miles 3.3 – 5.0 of the Cuyahoga River including biological indices, fish community, and macroinvertebrate community, and habitat statistics. Data were collected between 1984 and 2002.

Indices			Fish Community			Macroinvertebrate Community			Habitat	
Year	IBI	IWB	ICI	Num	Rel Wght	Rel Spp	Mean Taxa	Total Taxa	Qual	QHEI
1984		2.3		24	8.6	3.7				22.0
1985		5.6		422	13.0	4.0				
1987		1.6		61	15.8	2.7	23	3		20.0
1988		4.7	10	184	55.6	5.7	24	3		
1991		5.2	10	253	19.7	6.0	28	19		27.0
1994		5.5		260	42.3	7.3	41	10		31.0
1996	33	5.7	8	156	2.0	9.0	20	12		33.0
2002		5.5		356	26.9	7.0				

the number and type of species or taxa present in a river are associated with a range of disturbance factors in their environment, and thus, existing river integrity (“health”) can be estimated based on community compositions. The Invertebrate Community Index (ICI) in the Cuyahoga River for 1984, 1991, and 1996 decrease towards the mouth of the river, and scores for all three sampling years are at or below 30 in the last 10 river miles, suggesting that this area can not support a diverse or ecologically-sensitive macroinvertebrate community. Although the ICI for river mile 5.0 improved between 1984 (score of 12) and 1991 (score of 32), the ICI dropped again in 1996 to 25. The ICI scores reported in 1988, 1991, and 1996 by the State of Ohio EPA (Table 3) are significantly lower. The total number of invertebrate taxa present in the stretch of river that runs through the RDZ (river miles 3.26 – 5.0) fluctuates around 24 without much improvement, except for 1994 data, which reported 41 taxa present.

Although macroinvertebrate communities do not show signs of recent improvement, fish communities have shown

some recent recovery. The Index of Well Being (IWB) indicates that fish communities are slowly improving, even though scores are still relatively low (Table 3). Numbers of individuals and mean species have been steadily increasing from 1984 to 2002, although specific species are not identified in Table 3.

Fish community data for river miles 4.2 – 5.0 in the RDZ from 1987 – 1996 are summarized in Table 4. These data support Table 3 in that they show that fish communities have been improving from 1987 to 1996, in both number of individuals and number of species. However, in a recent report issued by the U.S. Army Corps of Engineers (2004), concern is expressed about the Federal Navigation Channel due to sharp declines in larval fish communities in the stretch. The declines in larval fish numbers (compared to farther upstream) are attributed to annual dredging of the Federal Navigation Channel, lack of riparian habitat, and very low dissolved oxygen in the water (U.S. Army Corps of Engineers, 2004). Some the species found in the greatest numbers in the area under investigation, such as common

Table 4. Summary of fish community data for lower Cuyahoga River..

Year	River Mile	Total Individuals	Relative Individuals	Number of Species	Dominating Species (in order of most common to less common)
1987	5.0	102	71.5	8	Common Carp, Gizzard Shad, Emerald Shiner, White Bass
1991	5.0	253	253	8	Gizzard Shad, Common Carp, White Bass
1993	5.0	474		4	Gizzard Shad
1994	4.8	391	260.6	11	Gizzard Shad, White Bass, Common Carp, White Perch
1996	4.8	156		15	Gizzard Shad
1996	4.2	742	773.2	22	Gizzard Shad, Emerald Shiner, Common Carp

carp, gizzard shad, and emerald shiner, are tolerant of degraded habitat and poor water quality. Pollution-intolerant species in moderate numbers, of which we presently have no evidence in this stretch of river, would be an indication that water quality and habitat has improved.

Terrestrial landscape

The RDZ (river miles 3.26 – 5.0) is located within the Federal Navigation Channel (river miles 0 – 5.6). The majority of the riparian area (82.5%) is occupied by bulkheads, while the remaining 17.5% of undeveloped land has been described as severely littered by construction debris and heavily vegetated (U.S. Army Corps of Engineers, 2004). The riparian zone in this area lacks a floodplain or wetlands, both of which would act as a retention and treatment area for floodwaters and would host native vegetative communities. Soils in many parts of the RDZ are severely impacted with hydrocarbons left behind from decades of petroleum product distribution and processing. Any landscape restoration would first require extensive soil evaluation to investigate soil quality.

Recommendations for Restoration

The RDZ on the Cuyahoga River presents some difficult yet intriguing possibilities of riverine landscape restoration. The difficulty arises from the “extreme” industrial landscape surrounding the river, the general poor water quality and habitat structure in the river and its tributaries, the remoteness of the site, and the continual dredging and large-ship use of the river. The Cuyahoga River RAP (U.S. Army Corps of Engineers, 2004) identified 15 factors that have impaired beneficial use of the Cuyahoga River, most of which relate to the fish and wildlife use of the river, including restrictions on fish and wildlife consumption, fish and other animal

deformities, and degradation of benthos.

The intrigue is because this location is almost ground-zero of the worst of the USA’s water pollution woes in the late 1960s; any restoration of a significant portion of the lower Cuyahoga would send a strong message to visitors that Cleveland is more than just concrete and steel. Restoration of even a remnant of the meandering riverine ecosystem that once was present here and connected to the Great Lakes (and was probably one of the reasons for the initial settlement) would be a wonderful urban green jewel in Cleveland and Cuyahoga County, Ohio.

Our recommendations on restoration are done in two parts. First, we present the concept and components of our successful urban riverine restoration project in central Ohio. While this “floodplain” restoration was done on what was mostly agricultural and not “brownfield” urban landscape, it has served to galvanize the local residents around a nature park in addition to providing habitat and water quality improvement for a major river. In the second part, we compare several alternatives that are not mutually exclusive that could enhance both biological and human use of the lower Cuyahoga River.

The concept

The idea to bring nature and people together in a semi-natural environment in the middle of urban areas is not new; Central Park in New York and the Forest Preserves in Chicago are prime examples. In some cases, the availability of a river system enhances both the possibilities and the interest on the part of people to use the site. One example of a river-fed restored urban environment that we are quite familiar with is our 30-acre wetland research park in Columbus, Ohio. The Olentangy River Wetland Research Park (ORWRP) in Columbus, Ohio provides a model of what is possible in urban lands adjacent to medium-sized

streams. The only major difference between the ORWRP and the RDZ is that the land in Columbus was mostly used for agricultural experimentation for the past 100 years, while the site on the Cuyahoga River has been under heavy industrial use for the past century. That may not be a trivial difference; however, there are several design concepts at the ORWRP that could translate nicely to Cleveland and the Cuyahoga River.

1. Created wetlands utilizing adjacent river water—There are about 12 acres of deepwater marsh wetlands at the ORWRP that are fed by river water from the Olentangy River. Some are fed by water pumped continuously from the river and one is fed by river water that enters the wetland during river pulses. These wetlands provide habitat for a number of organisms that are interesting to the urban population, including wading birds (herons, egrets), waterfowl, snapping turtles, bullfrogs, painted turtles, and several species of fish. Because deep areas (> 2 ft) are maintained in the wetlands for fish to over-winter, mosquitoes are not a problem in the urban area. Boardwalks, if maintained, can be an additional feature for the urban community.

2. Bikepaths—In order to have a nature site that people can enjoy, visitors have to be able to get to and across the site easily. The ORWRP has over a mile of city and university bike paths through its 30 acres. They are among the most frequently used bike paths in central Ohio.

3. Nature observation tower—A tower with a wheelchair ramp provides a very nice 2.5 story “duck-blind” view of the wetlands. Wildlife and bird observations are greatly enhanced from this vantage point and the tower at the ORWRP—called the Sandefur Wetland Pavilion—is popular with the local residents in Columbus.

4. Interpretative signs—There are a dozen interpretive signs at the ORWRP that translate nature and natural experiments for the public (Figure 20). Most of these are adjacent to the bikepaths.

5. Bikepath shelter—Soon, an AEP bikepath shelter at the ORWRP with a solar collector on the roof that will run displays relevant to nature and solar energy. The solar power will also run a bike tire pump.

While all of these features may not be appropriate or even necessary at the RDZ site, they are all proven elements of what is fast becoming one of the most visited natural areas in urban Columbus and a site that could be a model for any ecological restoration that might take place in the RDZ site.

A comparison of restoration alternatives

Costs and metrics of restoration alternatives evaluated in detail in this study for the lower Cuyahoga River in general are summarized on Table 5. Each of these alternatives is discussed below in detail and summarized here. Estimated costs per stream mile were lowest for the oxbow wetlands and pocket wetlands but cost per acre of ecosystem (wetland and/or stream) was lowest for the oxbow wetland (\$42,000 - \$71,000/acre) compared to the Kingsbury Run restoration (\$300,000 - \$900,000/acre) or

the pocket wetlands (\$500,000/acre). The oxbow wetlands would retain considerably more nonpoint source pollution, including sediments and phosphorus, than would the other two stream/wetland options although our preliminary estimates suggest that the stopped or reduced dredging would provide the most sediment and phosphorus retention, simply because of the accumulation of sediments in that location at least over the short term. Each of the first three options would result in different river/stream/wetland systems and no value judgment is given on one being more favorable over the other, e.g. a marsh, forested wetland, or river/stream system. We do believe that the oxbow wetlands would provide the most contribution to overall site diversity and would probably result in the highest overall IBI score.

But in a sense we are comparing apples and oranges because the oxbows would be ecosystems primarily adjacent to the Cuyahoga River, the pocket wetlands would be shoreline developments in the river itself, and the Kingsbury Run restoration would be on a tributary entering the Cuyahoga River. All three options could contribute to an enhanced fisheries in the River but without improvement in water quality upstream, none would not be very effective. At least the Kingsbury Run and oxbow systems could be maintained as systems somewhat independent of the “downstream” Cuyahoga River.

Restoration alternative I—oxbow wetlands

The creation of riparian oxbow wetlands that might have once existed on the floodplain of the Cuyahoga River is our first recommended alternative for significant water resource restoration in the lower Cuyahoga River (Figure 8). Through a unique design we have established at our “billabong wetland” on the Olentangy River in Columbus, the oxbow wetland recommended here could be established at such an elevation to seasonally “flood” from the Cuyahoga River, bringing in biological propagules (fish fry, eggs, plant seeds, etc.) that would allow the oxbow wetland to develop with little human introduction of plants or animals. The wetland could also be connected through an outflow to the river so that fish could move in and out of the wetland during high water. Creation of several of these “backwater” wetlands on the floodplain would provide a refuge, nursery, and source of food for fish as well as a conduit for fish to return back to the river. Thus these wetlands could enhance the fisheries in the river perhaps better than would restoration of an adjacent stream or on the river edge. The concept of creating adjacent wetlands to improve the fisheries in adjacent bodies of water is becoming better understood. For examples, studies in New Jersey are showing that salt marsh restoration adjacent to the Delaware River are providing important habitat for fish that spend most or some of their adult life in the river itself (Able et al., 2004; Nemerson and Able, 2005). Additionally, these wetlands would provide some water quality enhancement and floodwater retention for the Cuyahoga River and would provide a habitat for the return of fish-eating birds (herons, egrets, possibly osprey) to the lower floodplain of the Cuyahoga River.

Table 5. Cuyahoga River Valley restoration options & metrics

	Oxbow Wetlands ^a	Kingsbury Run restoration ^b	Pocket wetlands in Cuyahoga River ^c	Reduce dredging depth to 12 feet ^d	Stop dredging ^d
Area directly affected, acres	70 (oxbow) +44 (river) = 114 acres	2	44	154	154
Stream distance affected, mi	5.6	0.5 (run only)	5.6	5.6	5.6
1. Cost [per entire ship channel]	\$4.8 - 8.1 million	\$0.6 - \$1.6 million	\$ 11.35 million	\$0	\$0
Cost (\$1000) per ecosystem acre	\$42 - \$71	\$308 - \$915	\$516		
Cost (\$1,000,000) per stream mile	\$0.9 - \$1.4	\$1.1 - \$3.3	\$ 2		
2. Non-point runoff mitigation					
Potential quantity of rainfall retained during 1" storm event (acre-ft)	6	0.2	3.7	N/A	N/A
Maximum water retention, acre-ft	140	8	N/A		
Potential quantity of water retained from non-point sources (acre-ft/year)	4600	2700	2900	storage reduced	storage reduced
Sediments retained, metric tons/year	206	33	50	94,000	0
Phosphorus retained, metric tons/year	1.1	0.20	0.14	268	0
3. Wetlands Expected					
Wetland type	marsh/forest	Riparian vegetation	marsh possible	none	none
Water source and level	Nonpoint source/ Cuyahoga River	Kingsbury Run watershed	Cuyahoga River	N/A	
Wetland soil type	river alluvium	cobble/rock	river alluvium	N/A	N/A

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Vegetation (mix of cover and open water, and the height, arrangement, and density of wetland plants)	high density of plants; 50% open water	little vegetation except for trees and shrubs on edges	Low density of macrophytes; stressed by river flow and currents	N/A	N/A
Time-lag until effect complete	2 years	3 years	3 years	immediate effect	immediate effect
4. Ecosystem indicators					
IBI estimate for habitat	45-50 in wetland	35 in run	25 in river	25 in river	35-40 in river
Dissolved oxygen (mg/L ave.)	8.0 in wetland	5.0 in run	6.0-7.0 in river	6.0 in river	6.5 in river
CDI (community diversity index) ^e	>2.0	0.5	>1.0	0.0	0.0

^a Oxbow wetland

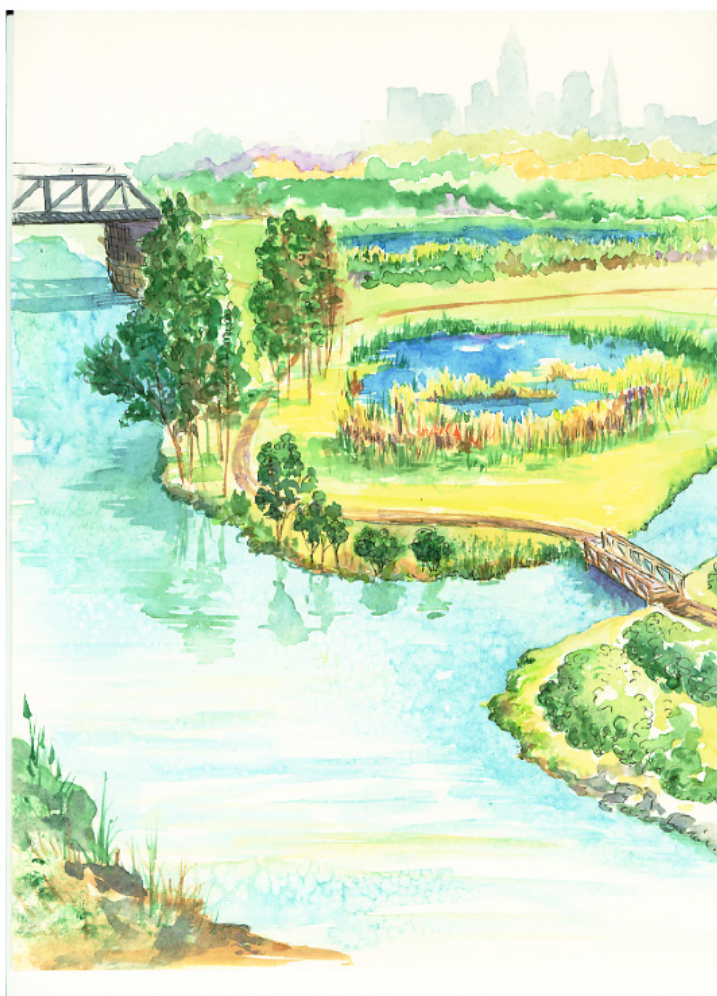


Figure 8. Restoration Alternative I: Creation of oxbow wetlands on flood plain terraces.

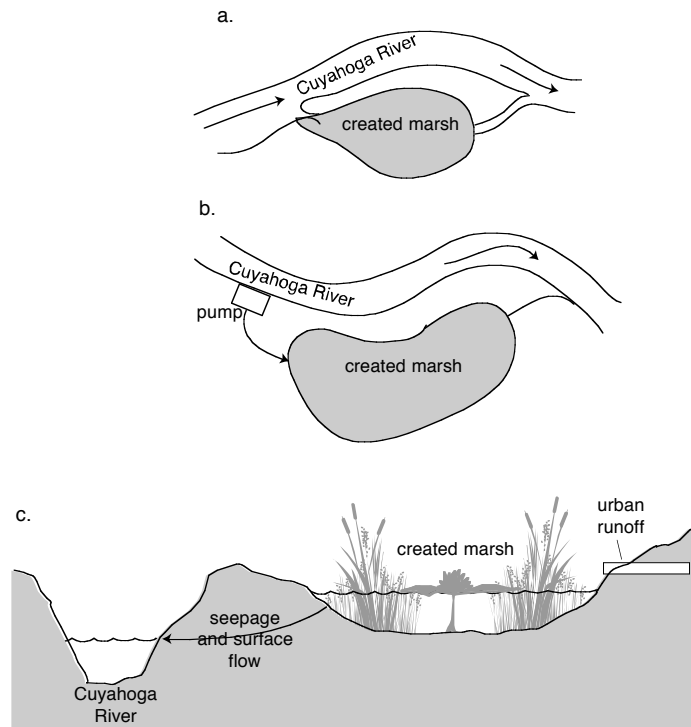


Figure 9. Potential sources of seasonal flooding for created terraces wetlands: a) natural flooding by Cuyahoga river; b) pumped water from Cuyahoga River; and c) stormwater runoff from urban uplands (from Mitsch and Gosselink, 2000; Mitsch and Jørgensen, 2004).

The wetlands could also be designed to receive significant amounts of stormwater runoff and even combined sewer overflow (although not as desirable if habitat is to be maximized) from the surrounding urban area. There are three possible sources of seasonal flooding for these riparian wetlands. First, water can seasonally flood this riparian wetland from pulses in the Cuyahoga River itself (Figure 9a) if elevations allow. This is the preferred technique. A second source is pumped water from the Cuyahoga River on a seasonal schedule (Figure 9b). Although somewhat “un-natural,” this has a distinct advantage of providing the best visual and possibly ecological landscape for the public to enjoy, even during low water periods. Furthermore, the pumping can be tied to a routine related to the river flow, with high pumping in the wet season and less pumping in the dry season. The disadvantage of using pumps is the commitment to maintenance and management; however a more attractive and potentially more biologically interesting wetland might result. The third possible water source is stormwater runoff from urban uplands and/or from Kingsbury Run (Figure 9c). In all cases, seasonal connections between the wetlands and the Cuyahoga River would ensure that some continual introduction of fish species would occur in the river without the disadvantage of disruption by dredging and shipping activity or seasonally poor water quality. The effective use of bikepaths and remnant industrial icons would provide

a more interesting location for Clevelanders to visit these wetlands in nice weather. Boats would not be required to appreciate their important functions.

We estimate that 70 acres of these wetlands (about 10% of the RZD area but along the entire lower Cuyahoga River) would cost \$4.8 to \$8.1 million for construction and that they would provide that area of habitat for fish and wildlife in addition to another 44 acres of river benefit (same as pocket wetland). Thus the cost per unit area of aquatic ecosystem restored is \$42,000 - \$71,000 (Table 5). The large area of the wetlands and their connection to both stormwater flow and river flooding suggest that they could receive 4600 acre-ft of water annually, treat 206 tons of sediments, and 1.1 tons of phosphorus each year (Table 5).

Restoration alternative II—Kingsbury Run restoration

Alternative II involves the restoration and “daylighting” of the tributary Kingsbury Run and is illustrated in Figure 10. Kingsbury Run restoration may be more appropriate than any restoration efforts in the Cuyahoga River itself due to dredging and large ship use in the latter waterway (see also discussion below of RAP recommendations). Kingsbury Run winds aboveground and often belowground in the RDZ before discharging into the Cuyahoga River at approximately Mile 4.4. The land along and above the stream is strewn



Figure 10. Restoration alternative II: Kingsbury Run restoration

with industrial waste materials and the soil is polluted with oil residue. Our concept, as illustrated in the rendering in Figure 10, is to return the entire stream in the RDZ to aboveground (daylighting), to grade and develop its riparian edge by planting trees typical of early succession riparian forests of the region (e.g. Eastern cottonwood, silver maple, swamp white oak), to import clean topsoil as necessary in the surrounding uplands which could be pocketed with ponds and wetlands, and to provide thoroughfares for human movement, particularly bikepaths.

The ecology of the stream would have a better possibility to develop an interesting fish community if the stream were restored with riffle and pool sequencing (Figure 11). While the stream would be formally connected to the Cuyahoga River, it would not be subjected to the annual river dredging and large ship turbulence so good habitats for invertebrates and fish could result if upstream stormwater flows are managed and have sufficient water quality.

Some features of the urban past, particularly the large abandoned bridge, are shown in the rendering in Figure 10 and could be left in place as a reminder of the industrial past as well as a convenient location for a nature outlook (if it is structurally safe). For both alternatives, the restoration

should include reminders of the important industrial past of this location.

The restoration costs for urban streams are highly variable and can range from thousands to hundreds of millions of dollars depending on the conditions of the stream being restored. Considering the highly modified and degraded nature of Kingsbury Run, costs will most likely fall within the upper range of typical restoration costs for urban streams. Concrete channels and culverts that currently direct the stream will need to be removed in order to restore the natural channel. The cost to reconstruct a stream channel, including widening or narrowing and meanders, is estimated to be between \$106 and \$315 per linear foot per bank for urban streams. In-stream fish habitat improvement costs, riparian forest buffer, filter strip, and streambank stabilization costs are variable and depend on the design (Table 6). A 100-foot wide riparian buffer is recommended for both sides of the bank for the length of the entire stream. This buffer will effectively reduce nutrient concentrations in runoff that reaches the stream, while adding stability to the bank and shading essential for fish habitat. Filter strip and riparian forest buffer costs in Table 6 are reported per foot of 100 foot-wide riparian buffer (i.e., it is assumed that a 100 foot buffer zone will be restored).

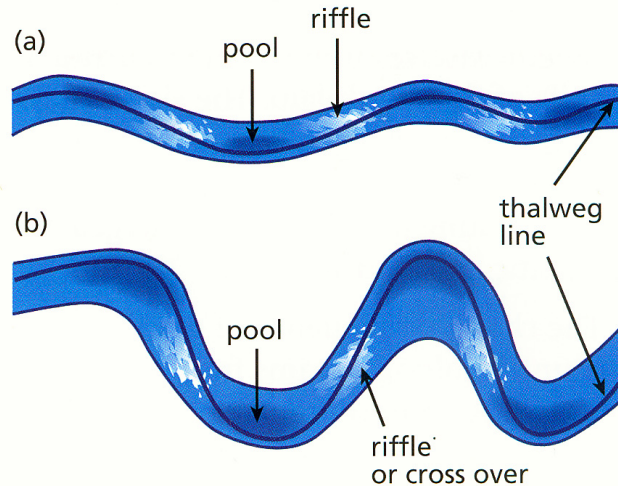


Figure 11. Riffle and pool sequencing in natural streams (from Federal Interagency Stream Restoration Working Group, 1998)

Table 6. Average costs per unit for stream restoration work (from Kelly 2001).

Practice	Component	Units	Unit average cost
Filter Strip	Site prep and seedling	foot	\$5
Riparian Forest Buffer	Site preparation	foot	\$1
	Tree planting	foot	\$8
	Tree shelters	each	\$3
	Seeding	foot	\$4
Fish Habitat Improvement	Stream boulder placement	each	\$50
	Log/wood frames	linear foot	\$3
	Rock riprap	cubic yard	\$50
Streambank Stabilization	Brush matting	linear foot	\$6
	Plant cuttings	each	\$0.50
	Fiber rolls	linear foot	\$12
	Live stakes	each	\$2
	Erosion control blanket	square yard	\$2
	Herbaceous plants	each	\$2

Estimates of Kingsbury Run streamflow and watershed area were not available for this study and are probably not known. From available maps, we estimated that 0.5 mile of the run could be restored and that the effective ecosystem area improved is 2 acres and the contributing watershed is approximately 1000 acres. We used a range of \$106-\$315 per foot of restoration for streams and rivers provided by North Carolina (2004) data. We would expect no improvement in the Cuyahoga River with the Kingsbury Run restoration until such time that the water quality improves in the river proper by reducing upstream pollution sources.

Restoration alternative III—Pocket wetlands on the Cuyahoga River

The Cuyahoga River RAP report (U.S. Army Corps of Engineers, 2004) identified several alternatives for enhancing habitat in the river Cuyahoga River channel itself by altering the mostly steel sheet pile bulkheads along the river shorelines (Figure 12). Those alternatives included the so-called “pocket wetlands” (Figure 12) which are low crested rock berms parallel to abandoned or undeveloped riverbanks. In most cases, these re-creations of shallow slopes on the edges of the river would require the complete removal of the steel bulkheads along the river. This alternative was

proposed to provide shallow water habitat structure along the Cuyahoga River to enhance the survivability of both larval and adult fish. Re-contouring of the Cuyahoga River shoreline from ridged edges or sharp gradients to more gentle gradients to these pocket wetlands would, in principle, provide a suitable habitat for a number of desirable fish species in the mainstream of the river.

This alternative is estimated to cost about \$9,600 per 50 foot of enhanced shoreline (USACOE, 2004). It is not clear given the turbulence and subsequent turbidity caused by passing ships that any “edge” aquatic plants would survive in such a system. We estimate that the pocket wetlands would retain about 20% of the river sediments and phosphorus. Overall, it would retain considerably less sediments and phosphorus than the oxbow wetlands.

Other restoration alternatives

Several other restoration alternatives were presented in the Cuyahoga RAP report that involved considerable use of mechanical devices to create artificial habitats. These included: LUNKERS (Little Underwater Neighborhood Keepers Encompassing Rheotactic Salmonids) along undeveloped riverbanks; cutback of existing sheet pile wall to 3-4 feet below water surface; suspended habitat beds suspended rigidly along steel sheet pile bulkheads; and suspended habitat beds suspended by floating buoys along steel sheet pile bulkheads.

We are not as positive on these RAP alternatives as they all involve artificial structures or gadgets that would have to be continually maintained and would have to be done so on a large scale to make any effective difference to the river. We do not believe that submersed aquatic plants will be successful in these projects because of the ship turbulence and turbidity problems. Most importantly, these systems do little to improve water quality per se and are simply ways to provide the physical structure of diverse habitats. A massive number would be required to make a significant impact on river fisheries. The improvement in water quality in the Cuyahoga River and probably a ceasing of dredging would be required for these alternatives to be effective.

River dredging and water quality improvement

In order for the lower Cuyahoga River to be an important aquatic ecosystem, two major changes must take place. First, the upstream water quality, including nonpoint source pollution from combined sewer overflows and other sources, need to be substantially controlled. Second, the dredging of the channel has to stop. Without improved water quality, established ecosystem structure will do much good to enhance fisheries and other aquatic life. With continued dredging, resuspension of polluted sediments and disruption of benthic habitat will hamper any river recovery. We recommend that cessation of dredging of the lower Cuyahoga be considered if it is at all feasible.

Dredging of the lower Cuyahoga River, while important

for ship traffic, creates an imbalanced stream ecosystem. A healthy stream has areas of erosion and areas of deposition but in those systems, the processes are in equilibrium. When an extensive amount of sediments is removed from a stream channel, the first thing that will happen is that stream will fill in again with new sediments, seeking the equilibrium that it had before. The excessive sedimentation that occurs then prevents the development of sustainable benthic biological communities. A stream or river without a healthy benthic community is rarely going to provide a diverse fishery. It is our opinion that river dredging is incompatible with restoring a healthy stream.

The use of the lower river as a dredged navigation channel is also not compatible with enhanced fisheries until the dredged sediments are naturally cleaned with time. That sediment “cleansing” will take decades, even if pollution sources are completely removed. Therefore, we prefer the option of initially enhancing fisheries and wildlife on the adjacent terraces (oxbow wetlands), tributary streams (e.g., Kingsbury Run), and riparian edges that have the possibility of starting with clean sediments and cleaner water until such time as the water quality and sediments have become much improved. Long-term improvement in water quality in the river basin will do the most good in improving aquatic ecosystems. Coupled with an end to river dredging, the restoration alternatives discussed in this report will be much more effective.

Interactive effects of restoration techniques

No one restoration approach should be relied upon; rather all of the approaches described in this report should be attempted, first as demonstration-scale projects. A restored stream can provide inflow water to an oxbow wetland; pocket wetlands can be hydrologically connected to adjacent oxbow wetlands. Before any suite of projects is attempted, a thorough description of the hydrology, geomorphology, water quality, and biology of the lower Cuyahoga needs to be described. A full field study of the lower Cuyahoga River is needed (hydrology, sediment dynamics, water quality, soils, stream fisheries, vegetation restoration potential). The Olentangy River Wetland Research Park could lead that study; a similar study on the Olentangy River was estimated to cost \$350,000 for a 2-year study.

Planning an approach to restoration

Demonstration projects of each of the three alternatives presented here would be necessary before embarking on a full-scale restoration project. Complete monitoring should follow any demonstration project or there would be no point to doing the demonstration. These demonstration projects could be scaled to cost about \$500,000 each for design/construction and another \$300,000 for monitoring/research. So for \$800,000 for example, a 7-acre oxbow wetland could be built and monitored for 3 years. For \$2.4 million, all

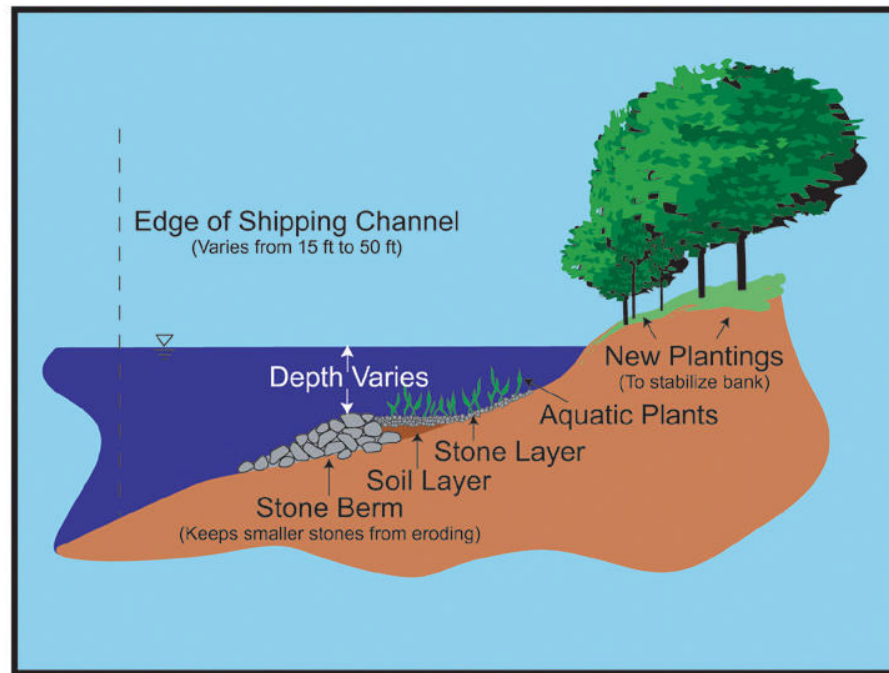


Figure 12. Pocket wetland restoration alternative for Cuyahoga River (U.S. Army Corps of Engineers, 2004)

three demonstration options could be attempted on site with perhaps some economy of scale on monitoring. Based on the results of these demonstration studies, the full system could be better designed. This could occur simultaneous with discussions on the cessation of channel dredging and improvement of the water quality of the river itself which both may take decades to occur.

A system of 70 acres of oxbows intercepting stormwater runoff, 0.5 miles Kingsbury Run restored, and bulkhead removal/pocket wetlands along 5.6 miles of the lower Cuyahoga would lead to a substantial improvement in the aquatic ecosystems of the Lower Cuyahoga Valley if, at the same time, the water quality were improved substantially upstream and dredging stopped or significantly curtailed. Excluding the unknown costs of brownfield site remediation which in all probability will be required along the lower Cuyahoga River, we estimate the implementation of a set of wetland and stream creation/restoration projects on the lower Cuyahoga River on a scale sufficient in scale to make a significant difference on aquatic fisheries of the river to be \$24 million (estimated from high end estimates in Table 5 with 50% increase for design and monitoring). Any smaller investment would probably not be on a scale sufficient to see measurable effects in the lower river.

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